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(71)Applicant : HITACHI LTD
HITACHI METALS LTD
(72)Inventor : KOMURO MATAHIRO
TAJIMA FUMIO
KURIYAMA YOSHIHIKO

(54) RING MAGNET, ITS MANUFACTURING METHOD, AND ROTOR AND MOTOR USING THIS RING MAGNET

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a ring magnet capable of realizing both of the reluctance torque and low cogging torque of a polar anisotropy magnet by using the difference between magnetic reluctance, by providing the difference of the magnetic reluctance in a circumferential direction of the ring magnet, and to provide its manufacturing method, and a rotor and a rotating machine using the ring magnet.
SOLUTION: In this ring magnet, a plurality of soft magnetic materials are integrally formed in annular rigid magnetic material of which the easy magnetization direction periodically varies in a circumferential or diametrical direction at a certain interval in the circumferential direction. This manufacturing method of the ring magnet has a forming process of a compound body in which the plurality of soft magnetic materials are disposed at a certain interval in the peripheral direction in the rigid magnetic material particulates disposed in a ring shape, a pressure forming process in which a pressure forming body is formed while the compound body is disposed in a magnetic field, and a sintered process in which the press forming body is sintered.

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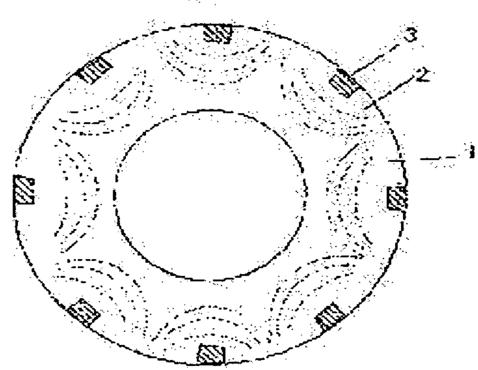

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CLAIMS

[Claim(s)]
[Claim 1]
The ring magnet characterized by forming two or more soft magnetism material at fixed spacing in the hoop direction at one in the ring-like hard magnetism material from which the easy magnetization direction changed periodically in the hoop direction or the direction of a path.
[Claim 2]
The ring magnet characterized by embedding [at least at one side by the side of the periphery of the ring-like hard magnetism material from which the easy magnetization direction changed periodically in the hoop direction or the direction of a path, or inner circumference] two or more soft magnetism material at fixed spacing in a hoop direction, and being formed in one.
[Claim 3]
The ring magnet characterized by embedding [at least at one side by the side of the periphery of the ring-like hard magnetism material from which the easy magnetization direction changed periodically in the shape of a sine wave in the hoop direction, or inner circumference] two or more soft magnetism material at fixed spacing in a hoop direction, and being formed in one.
[Claim 4]
The ring magnet characterized by forming in one two or more soft magnetism material by which the easy magnetization direction was missing from the periphery side, and continued from the inner circumference side in the hoop direction in the ring-like hard magnetism material which changed periodically in the shape of a sine wave at fixed spacing in the hoop direction.
[Claim 5]
It is the ring magnet characterized by forming said hard magnetism material and soft magnetism material in one of sintering in either of claims 1-4.
[Claim 6]
It is the ring magnet with which said hard magnetism material and soft magnetism material are characterized by said thing [being sintered] after pressing in a field in either of claims 1-5.
[Claim 7]
The easy magnetization direction [in / on either of claims 1-6 and / in said soft magnetism material / the hoop direction of said hard magnetism material] is the ring magnet characterized by being formed in the location suitable for said hoop direction.

[Claim 8]
The manufacturing method of the ring magnet characterized by having the formation process of the complex which arranges two or more soft magnetism material at fixed spacing to the hoop direction in the hard magnetism material powder arranged in the shape of a ring, the pressing process which forms a pressing object while carrying out orientation of said complex in a field, and the sintering process which makes said pressing object sinter.
[Claim 9]
The manufacturing method of the ring magnet characterized by having the formation process of the complex which arranges two or more soft magnetism material at fixed spacing to a hoop direction at least at one side by the side of the periphery in the hard magnetism material powder arranged in the shape of a ring, or inner circumference, the pressing process which forms a pressing object while carrying out orientation of said complex in a field, and the sintering process which makes said pressing object sinter.
[Claim 10]
The manufacturing method of the ring magnet characterized by to have the formation process of the complex which arranges two or more soft magnetism material which was missing from the periphery side and followed the part in the hard magnetism material powder arranged in the shape of a ring from the inner circumference side at fixed spacing to a hoop direction, the pressing process which forms a pressing object while carrying out orientation of said complex in a field, and the sintering process which makes said pressing object sinter.
[Claim 11]
The manufacturing method of the ring magnet characterized by adjusting said direction of a field in either of claims 8-10 so that the easy magnetization direction of the hard magnetism material of the shape of said ring may change periodically in a hoop direction or the direction of a path.
[Claim 12]
It is the manufacturing method of the ring magnet characterized by carrying out pressing all over the magnetic field of the direction where said soft magnetism material becomes in the direction of a path about soft magnetism material powder in either of claims 8-11, or a non-magnetic field.

[Claim 13]
The manufacturing method of the ring magnet characterized by the easy magnetization direction of said hard magnetism material arranging said soft magnetism material in the location suitable for said hoop direction in either of claims 8-12.
[Claim 14]
The rotator characterized by said ring magnet becoming the periphery of a shaft from a ring magnet according to claim 1 to 7 in the rotator which has a ring-like magnet.
[Claim 15]
The rotator to which said ring magnet is characterized by consisting of a ring magnet formed of the manufacturing method of a ring magnet according to claim 8 to 13 in the rotator which has a ring-like magnet on the periphery of a shaft.
[Claim 16]
The rotating machine characterized by said rotator consisting of a rotator according to claim 14 or 15 in the rotating machine which has a stator and a rotator turning around the inside of this stator.
[Claim 17]
The rotating machine characterized by cogging torque being 5% or less to a rating torque in claim 16.

[Translation done.]

* NOTICES *

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]
This invention relates to a rotating machine at a new ring magnet, its manufacturing method, and the rotator list using it.
[0002]
[Description of the Prior Art]
[Patent reference 1] JP,2000-269062,A
[Patent reference 2] JP,2000-195714,A
The anisotropy from which the easy magnetization direction changed continuously in the conventional ring magnet in the hoop direction
About a magnet
[Patent reference 1] **
[Patent reference 2] It is alike and is indicated. By these well-known examples, in the process which carries out magnetic powder shaping, the orientation of the magnetic powder was made to carry out in the direction of a field, and the easy magnetization direction has gathered in the direction of orientation of magnetic powder by the field with a coil etc. Making it sinter after the orientation of magnetic powder and shaping, and creating the polar anisotropy magnet in which the easy magnetization direction changed in the hoop direction, and the magnet after sintering had high magnetic properties is indicated.
[0003]
[Problem(s) to be Solved by the Invention]
The ring magnet which was compatible in the reluctance torque and the low cogging torque of a polar anisotropy magnet using the difference of magnetic reluctance is not shown by the Prior art. Moreover, making the hoop direction of the ring magnet which fabricated by one the powder of magnetic material with which magnetic properties differ for reluctance torque reservation arrange periodically is not shown.
[0004]
Artificers can secure the torque in a low rotational frequency, when reluctance torque could be used, and since [which needs big torque at a low rotational frequency] MOTAHE application was carried out, as a result of examining the structure of using reluctance torque, they found out preparing an elasticity part in the hoop direction of a hard ring magnetically. Moreover, although artificers could be realized by dividing a magnet into a hoop direction and making soft magnetism material insert between magnets in order to have produced such reluctance torque, they found out that there were problems, such as that reservation of magnetic process tolerance is difficult, that a magnetic adhesion process is the need, magnet maintenance at the time of rotation, and dispersion increase of surface inductive flux.
[0005]
Furthermore, when dividing a magnet for every pole, a surface magnetic-flux density wave form changes with configuration dispersion for every pole. When especially the diameter of a magnet varies, the magnetic flux in the teeth point of a stator differs for every pole. Adhesion of a magnet and soft magnetism material imitates the fall of a rotator on the strength, results, and leads to heterogeneity increase of the magnetic flux by the nonmagnetic gap of jointing.
[0006]

The purpose of this invention gives the difference of magnetic reluctance to the hoop direction of a ring magnet, and is to provide with a rotating machine the ring magnet which was compatible in the reluctance torque and the low cogging torque of a polar anisotropy magnet using the difference of magnetic reluctance, its manufacturing method, and the rotator list using it.
[0007]
[Means for Solving the Problem]
This invention is in the ring magnet which reconciled the reluctance torque and the low cogging torque of a polar anisotropy magnet using the difference of magnetic reluctance. if reluctance torque can be used, it becomes possible to secure the torque in a low rotational frequency, and torque is required of a low rotational frequency -- MOTAHE application can be carried out. In order to use reluctance torque, it is necessary to prepare an elasticity part in the hoop direction of a hard ring magnetically. for producing such reluctance torque -- a magnet -- a hoop direction -- dividing -- between a magnet and magnets -- precision -- it can be high, and can realize by making soft magnetism material insert easily, and problems, such as magnet maintenance at the time of rotation and dispersion of surface inductive flux, can be solved.
[0008]
This invention is in the ring magnet characterized by forming two or more soft magnetism material at fixed spacing in the hoop direction at one in the ring-like hard magnetism material from which the easy magnetization direction changed periodically in the hoop direction or the direction of a path. Furthermore, this invention has the following requirements.
[0009]
The ring magnet characterized by embedding [at least at one side by the side of the periphery of the ring-like hard magnetism material from which the easy magnetization direction changed periodically in the hoop direction or the direction of a path, or inner circumference] two or more soft magnetism material at fixed spacing in a hoop direction, and being formed in one.
[0010]
The ring magnet characterized by embedding [at least at one side by the side of the periphery of the ring-like hard magnetism material from which the easy magnetization direction changed periodically in the shape of a sine wave in the hoop direction, or inner circumference] two or more soft magnetism material at fixed spacing in a hoop direction, and being formed in one.
[0011]
The ring magnet characterized by forming in one two or more soft magnetism material by which the easy magnetization direction was missing from the periphery side, and continued from the inner circumference side in the hoop direction in the ring-like hard magnetism material which changed periodically in the shape of a sine wave at fixed spacing in the hoop direction.
[0012]
As for the ring magnet of this invention, it is desirable that said hard magnetism material and soft magnetism material are formed in one of sintering and to be formed in the location the easy magnetization direction [in / material / said / hard magnetism material and soft magnetism material / in the inside of a field / in after pressing, said thing / being sintered /, and said soft magnetism material / the hoop direction of said hard magnetism material] turned [location] to said hoop direction.
[0013]
This invention is in the manufacturing method of the ring magnet characterized by having the formation process of the complex which arranges two or more soft magnetism material at fixed spacing to the hoop direction in the hard magnetism material powder arranged in the shape of a ring, the pressing process which forms a pressing object while carrying out orientation of said complex in a field, and the sintering process which makes said pressing object sinter.
[0014]
That is, through the process which makes the powder which carried out orientation of the powder of hard magnetism material to the process which carries out orientation by the field sinter, the part which shows soft magnetic characteristics fabricates this invention by hard magnetism material and one, and it makes periodic arrangement of the part which shows soft magnetic characteristics in a hoop direction.

[0015]
Moreover, this invention aligns a part with the high permeability which carried out shaping sintering from the powder of soft magnetism material at the part by the side of the periphery in the hard magnetism material powder arranged in the shape of [said] a ring, or inner circumference, and is fabricated.
[0016]
Or the part which shows the soft magnetic characteristics fabricated and sintered from the powder of soft magnetism material to the part by the side of the periphery of said ring or inner circumference makes it align a fixed period, and is fabricated in a hoop direction.
[0017]
The powder of hard magnetism material and soft magnetism material is used for this invention, and it has the process which makes the powder which carried out orientation to the process to which orientation of these powder is carried out by the field sinter. The easy magnetization direction of the hard magnetism material which forms the ring magnet is periodically changed in the shape of a sine wave in a hoop direction. There is a part with the high permeability which becomes the hoop direction angular position is the inner circumference side of said ring, and easy ****** of hard magnetism material turned [hoop direction] to the hoop direction mostly from soft magnetism material, and it is made to align a period with the part fixed in a hoop direction which shows soft magnetic characteristics.
[0018]
The process to which this invention carries out orientation of the powder of hard magnetism material and soft magnetism material by the field, The easy magnetization direction of the hard magnetism material of the ring magnet produced through the process which makes the powder which carried out orientation sinter is periodically changed in the shape of a sine wave in a hoop direction. A part with the high permeability which the easy magnetization direction of the hard magnetism material of said ring becomes from the soft magnetism material which followed the periphery side from the inner circumference side near the location it turned [location] to the hoop direction mostly is prepared, and the part which shows soft magnetic characteristics aligns a fixed period in a hoop direction.
[0019]
In the ring-like magnet produced through the process which makes the powder which carried out orientation of the powder of hard magnetism material to the process which carries out orientation by the field sinter, the part which shows soft magnetic characteristics fabricates this invention by hard magnetism material and one, and the wave of surface inductive flux has become a sine wave mostly after magnetizing a ring-like magnet by the external magnetic field added in the direction near the direction of orientation.
[0020]
As for adjusting said direction of a field so that the easy magnetization direction of the hard magnetism material of the shape of said ring may change periodically in a hoop direction or the direction of a path, and said soft magnetism material, it is desirable that the easy magnetization direction of said hard magnetism material arranges to carry out pressing of the soft magnetism material powder all over the magnetic field of the direction which becomes in the direction of a path, or a non-magnetic field, and said soft magnetism material in the location suitable for said hoop direction.
[0021]
Furthermore, this invention is characterized by that said ring magnet becomes the above-mentioned from the ring magnet of a publication, and consisting of a ring magnet formed in the above-mentioned of the manufacturing method of a publication in the rotator which has a ring-like magnet on the periphery of a shaft.
[0022]
Moreover, in the rotating machine which has a stator and a rotator turning around the inside of this stator, this invention is characterized by said rotator becoming the above-mentioned from the rotator of a publication, and especially in the motor, to the rating torque, its cogging torque is as small as 5% or less, and it has high induced voltage.

[0023]
[Embodiment of the Invention]
(Example 1)
Drawing 1 is the sectional view of the ring magnet which formed the soft magnetism section 3 in the hoop direction periodically at the pole edge periphery side of the radial ring magnet of this invention. The dotted line shows the direction 2 of orientation of the easy magnetization direction of the hard magnetism material 4. The direction 2 of orientation of the easy magnetization direction of the hard magnetism material 4 is the direction of a path, and the direction of orientation and a perpendicular direction are difficult shaft orientations.
[0024]
The hard magnetism material 4 contains the compound which consists of an element of at least one kind of rare earth metal, Fe, Co and B, or N, and especially, since the residual magnetic flux density is high, a NdFeB system, a NdDyFeB system, a NdFeCoB system, a SmCo system, a SmCoFe system, a SmFeN system, and a SmCoZrN system can make induced voltage high. The powder of these hard magnetism material is carried out after presentation adjustment and particle-size-distribution adjustment, orientation of the magnetic flux is carried out in the specific direction for said powder as a magnet by the field, and it is used. Moreover, the soft magnetism material 3 is arranged with the pole and the same number in the periphery section of a ring magnet. Since Fe alloy becomes [permeability] high, the soft magnetism material 3 is the optimal, and Fe-Si, Fe-A1, Fe-B, its Fe-C, etc. are good.
[0025]
A sintering process is explained below from orientation. The introduction soft magnetism material 3 is fabricated by the two or less 1 - 10 t/cm pressure using the shaping metal mold of a square-like long picture. The field under shaping makes a field impress in a non-magnetic field or the direction of RAJIARU, and the becoming direction. To the above-mentioned Fe alloy powder, stearin acid is added about 1% as lubricant, and it fabricates, after often mixing. The Plastic solid of the powder of soft magnetism material is mostly arranged at equal intervals to a hoop direction at the periphery side of orientation metal mold. Simple things of a perpendicular cross-section configuration, such as a round head, a trigonum, and an ellipse, are [the soft magnetism material 3] good for others to the longitudinal direction.
[0026]
Next, the Plastic solid of the soft magnetism material 3 is arranged to the periphery side in double cylinder-like metal mold, and the powder of the above-mentioned hard magnetism material 4 is poured in into the metal mold. The crevice of the same configuration is prepared and it, die length, and width of face are inserted in there so that a part of Plastic solid of the soft magnetism material 3 can insert in the periphery side in metal mold, and it is made not to move at the time of impregnation of the powder of the hard magnetism material 4, and pressing. Moreover, the die length of metal mold is large so that it may be long and may become the die length same after pressing as the Plastic solid of the soft magnetism material 3 from the Plastic solid of the soft magnetism material 3, and the pressurization side is prepared straight. By the field from a coil or a magnet, the orientation of the powder of the hard magnetism material 4 is turned to a radial direction, and carries out pressing. Compacting pressure is 1 - 10 t/cm2. If the powder of a NdFeCoB system with a particle size of 1-3 micrometers is used, the direction of a path or radial direction shown in the direction 2 of orientation of the easy magnetization direction of the hard magnetism material 4 of drawing 5 can be made to carry out orientation by impressing the field of 8000Oe. The amount of preferred orientation of the powder of the hard magnetism material 4 at this time is 80% or more. Exact arrangement of the Plastic solid of the soft magnetism material 3 is obtained by this metal mold.
[0027]
Thus, the powder which carried out pressing is made to sinter in a vacuum (1x10 to 2 Pa degree of vacuum). First, presintering is carried out at 400-500 degrees C. Lubricant evaporates at this time. 800-degree-Cor more NdFe4 B4 which is 1200 degrees C or less (5 hours), and is a phase (Nd rich phase) with many amounts of Nd(s) from Nd2(Fe, Co) 14B (the main phase) and Nd2 (Fe, Co)14B generates sintering temperature. This Nd rich phase serves as a role of a binder, and the

interface of the soft magnetism material 3 and hard magnetism material is also sintered. Moreover, few ring magnets of the variation in the configuration for every pole are obtained also even for after sintering by exact arrangement of the Plastic solid of the soft magnetism material 3 at the time of sintering.

[0028]

After sintering, in order to make coercive force increase, it heat-treats again at 600-degree-C or more temperature of 1000 degrees C or less (5 hours). The particle size of the main phase after heat treatment is 2-15 micrometers. A periphery inside-and-outside periphery is processed after heat treatment, and it becomes a ring magnet like drawing 1 . This ring magnet is eight poles and the soft magnetism material 3 is arranged with the pole and the same number at the periphery side. The location of one soft magnetism material is 5 - 10% of the include angle of one pole in a hoop direction. In the direction of a path, it is producing by 3 - 10% of thickness.

[0029]

(Example 2)

Drawing 2 is the sectional view of the ring magnet which formed the soft magnetism material 3 in the hoop direction periodically at the pole edge periphery side of the polar anisotropy ring magnet of this invention. In drawing 2 , the hard magnetism material 1 is a ring configuration, and the direction 2 of an easy axis of the hard magnetism material 1 is changing periodically in the hoop direction. The soft magnetism material 3 is periodically arranged so that the front face of the soft magnetism material 3 may appear in a periphery side by the same peripheral surface, and it is the magnet of one as a whole. The object as an example 1 with the same quality of the material of the hard magnetism material 1 is used.

[0030]

Iron powder is used for the soft magnetism material 3. Zinc stearate is added about 1% as lubricant into electrolytic iron powder with a particle size of 5-20 micrometers, it inserts in mixed backward metal mold, pressing is carried out like an example 1, and it considers as a long square-like configuration. The magnetic powder of a NdFeB system is used for the hard magnetism material 1. The particle size of NdFeB system magnetism powder is 3-15 micrometers. In order to make an energy product high, single crystal powder with a mean particle diameter of 3-5 micrometers is used. The Plastic solid of the soft magnetism material 2 inserts this magnetic powder into the metal mold arranged at the periphery side. Then, it fabricates by the ** mosquito of 1 t/cm2 in the field of 8000Oe. The direction of a field is controlled by the coil arranged to the periphery [of metal mold], or inner circumference side along the easy magnetization direction 2 of the hard magnetism material of drawing 2 , and a field is impressed at the time of shaping. The direction of a field with a coil is changed continuously [a hoop direction] within a ring, and periodically.

[0031]

In drawing 2 , what has been arranged at the periphery [of the magnetic powder insertion section] or inner circumference side according to a pole in eight pairs of field impression coils was used, and the direction of a field designed the coil location so that it might become a sine wave mostly in a hoop direction, and it has applied it to metal mold. The current passed in a coil is 1x106 A/cm2, and is adding pulse current at the time of shaping. The field for carrying out orientation of the hard magnetism material is added, and the c-axis of ****** which is the easy magnetization direction of Nd2Fe14B arranges after shaping along the direction 2 of orientation of the easy magnetization direction of the hard magnetism material of drawing 4 . The c-axis of Nd2Fe14B has arranged after sintering and sintering and heat treatment as well as an example 1 along the easy magnetization direction 2 of hard magnetism material shown in drawing 4 . It considers as a ring configuration after sintering and heat treatment by processing by the diamond or the grinding stone, or processing by wire cut, Nd2Fe14B is magnetized using magnetization York (15 or more kOes of fields), it becomes the ring magnet of drawing 2 , and, as for a ring magnet, the permeability of a hoop direction changes periodically.

[0032]

The configuration of the soft magnetism material 3 is the width of face of 1/2 or less hoop direction of the include angle of one pole with 8 pole ring magnet, and, as for the direction of a

path, it is desirable to carry out to 1/2 or less [of the direction thickness of a path] in the location by the side of a periphery, and to suppose that it is the same as that of an example 1. If the rate of the volume of the soft magnetism material 3 of the direction of a path becomes 1/2 or more, the waveform distortion of surface inductive flux will become 5% or more, and the peak value of surface inductive flux will also fall. Moreover, if the soft magnetism material 3 of a hoop direction becomes 1/2 or more, the waveform distortion of surface inductive flux will increase remarkably.

[0033]

(Example 3)

This example is replaced with Nd2Fe14B as hard magnetism material 1 of an example 2, is a thing using a SmCo system and is made to equalize by solution treatment at temperature lower than sintering temperature in the case of a SmCo system. The powder of Sm2Co17 is inserted in the metal mold with which the soft magnetism material Plastic solid has been arranged like an example 2, and pressing is carried out, impressing an orientation field. Electrolysis Fe powder is used for the soft magnetism material 3. The moulding pressure mosquitoes of electrolysis Fe powder are about 5 t/cm2. The field at the time of an Sm2Co17 powder shaping form is 7000 or more Oes, and makes the orientation of the c-axis carry out in the direction of a field. The pressure at the time of shaping is 1 - 10 t/cm2. Presintering of the Plastic solid is carried out like an example 1 within a vacuum heating furnace, and it is heat-treated at 700-900 degrees C after sintering by further 1000-1200 degrees C. The ambient atmosphere at the time of sintering is hydrogen, inert gas, or a vacuum. By making a part of Co the presentation changed into Cu, an energy product (Bhmax) can obtain the ring magnet of 90 kJ/m3 by the coercive force exceeding 10kOe.

[0034]

The orientation of Sm2Co17 after sintering changes periodically [in a hoop direction] and continuously, as shown in drawing 2 . The location of the coil of orientation York used for orientation shaping so that the easy magnetization direction may meet such orientation, or a magnet is designed. The coil or the magnet is using what has been arranged at the periphery [of the magnetic ring-like powder insertion section], or inner circumference side according to a pole. The configuration of the hard magnetism material 3 is the width of face of 1/2 or less hoop direction of the include angle of one pole with 8 pole ring magnet of drawing 2 , and, as for the direction of a path, it is desirable to carry out to 1/2 or less [of the direction thickness of a path] in the location by the side of a periphery, and to suppose that it is the same as that of an example 1. If the rate of the volume of the soft magnetism material of the direction of a path becomes 1/2 or more, the waveform distortion of surface inductive flux will become 5% or more, and the peak value of surface inductive flux will also fall.

[0035]

Moreover, if the soft magnetism material of a hoop direction becomes 1/2 or more, the waveform distortion of surface inductive flux will increase remarkably. If Sm2Co17 is magnetized and the permeability of the ring magnet of drawing 2 is measured after processing, it will check that permeability is high 5% or more by the periphery side of the soft magnetism material 3.

[0036]

Moreover, when the orientation of hard magnetism material 2 like drawing 2 changes continuously in a hoop direction, in the case of the same magnetic material, surface inductive flux is higher than drawing 1 in the same configuration. When it is the ring magnet from which the direction of an easy axis is changing to the hoop direction, the waveform distortion of surface inductive flux becomes [the one distant from the include angle, as for the location of the soft magnetism material 3, the absolute value of surface inductive flux indicates maximum to be] small. Then, it is made arrangement of the soft magnetism material 3 as shown in drawing 2 . In drawing 2 , the location of soft magnetism material is arranged to the mid-position of the include angle from which the absolute value of surface inductive flux serves as max, and an include angle. At the include angle from which the absolute value of surface inductive flux serves as max, the easy magnetization direction has become in the direction of a path mostly, and near the soft magnetism material 3, the orientation of hard magnetism material is turned to in the

direction near a hoop direction, as shown in drawing 2 . Such a ring magnet has high surface inductive flux, and induced voltage can be made high, and since the permeability of the part of the soft magnetism material 3 becomes large rather than 1.1, magnetic reluctance is changing periodically in the hoop direction.
[0037]
The same effectiveness can be acquired when the SmCo system of the hard magnetism material 1 of this example is used for an example 1.
[0038]
(Example 4)
Drawing 3 is the sectional view of the ring magnet which prepared the soft magnetism section in the hoop direction periodically at the inner circumference side of the polar anisotropy ring magnet of this invention. In drawing 3 , the hard magnetism material 1 is a ring configuration, and the direction 2 of orientation of the direction of an easy axis of the hard magnetism material 1 is changing periodically in the hoop direction. The soft magnetism material 3 is periodically arranged so that the front face of the soft magnetism material 3 may come out to an inner circumference side front face, and it is the magnet of one as a whole.
[0039]
Iron powder is used for the soft magnetism material 3. As lubricant, zinc stearate is added about 1% into 5-20-micrometer electrolytic iron powder, and it inserts in mixed backward metal mold at it. The magnetic powder of a NdFeB system is used for the hard magnetism material 1. Although chosen according to Nd2Fe14B, 2(M, Dy) Fe14B, 15(Nd, Dy) Fe 77B7A11, the magnetic properties of which 2 (Nd, Dy) (Fe, Co)14B is required, a manufacturing cost, and an operating environment, in order to produce the periodic change in the hoop direction of the permeability which is made to arrange the soft magnetism material 3 and is obtained, any of the above-mentioned NdFeB system and a SmCo system are sufficient as NdFeB system magnetic powder. Metal mold makes the periphery of an example 1 the same structure as inner circumference. A ring magnet with little variation is obtained by the configuration by it.
[0040]
The particle size of the used NdFeB system magnetism powder is 3-15 micrometers. In order to make an energy product high, single crystal powder with a mean particle diameter of 35 micrometers is used. This magnetic powder is inserted into the metal mold with which the Plastic solid of soft magnetism material has been arranged. Then, it fabricates by the pressure of 1 t/cm2 in the field of 8000Oe. The direction of a field is controlled by the coil by the side of the periphery of metal mold, or inner circumference along the easy magnetization direction 2 of the hard magnetism wood of drawing 3 , and a field is impressed at the time of shaping. The direction of a field with a coil is changed continuously [a hoop direction] within a ring, and periodically.
[0041]
In drawing 3 , eight pairs of field impression coils were used, and the direction of a field designed the coil location so that it might become a sine wave mostly in a hoop direction, and it has applied it to metal mold. The current passed in a coil is 1x106 A/cm2, and is adding pulse current at the time of shaping. The field for carrying out orientation of the hard magnetism material is added, and the c-axis of ****** which is the easy magnetization direction of Nd2Fe14B arranges mostly along the easy magnetization direction 2 of the hard magnetism material of drawing 3 after shaping. The c-axis of Nd2Fe14B has arranged after sintering and sintering and heat treatment as well as an example 1 along the easy magnetization direction 2 of hard magnetism material shown in drawing 3 . It considers as a ring configuration after sintering and heat treatment by processing by the diamond or the grinding stone, or processing by wire cut, Nd2Fe14B is magnetized using magnetization York (15 or more kOes of fields), and it becomes the ring magnet of drawing 3 .
[0042]
The configuration of the soft magnetism material 3 is the width of face of 1/2 or less hoop direction of the include angle of one pole with 8 pole ring magnet of drawing 3 , and the direction of a path is 1/2 or less [of the direction thickness of a path] in the location by the side of a periphery. If the rate of the volume of the soft magnetism material 3 of the direction of a path

becomes 1/2 or more, the waveform distortion of surface inductive flux will become 5% or more. It is desirable to suppose that it is the same as that of an example 1.

[0043]

If a ring magnet is produced only by the hard magnetism material 1, without arranging the soft magnetism material 3, it will become like drawing 4 . The orientation of the hard magnetism material 1 of drawing 4 is repeated by continuation and the periodic target in the hoop direction, and the direction 2 of orientation of the easy magnetization direction of hard magnetism material is repeated 8 times, as shown in drawing 4 . The permeability by the side of the periphery of a ring magnet like drawing 4 hardly changes in a hoop direction. Therefore, it is difficult to utilize reluctance torque.

[0044]

On the other hand, in order to obtain the sintered compact of the configuration of drawing 3 , when the permeability of the ring magnet which processes a ring configuration and magnetizes $Nd_2Fe_{14}B$ is measured, permeability is high 2% or more at the periphery side of the soft magnetism material 3. Moreover, when the orientation of hard magnetism material 2 like drawing 3 changes continuously in a hoop direction, in the case of the same magnetic material, surface inductive flux is higher than drawing 1 in the same configuration. When it is the ring magnet from which the direction of an easy axis is changing to the hoop direction, the waveform distortion of surface inductive flux becomes [the one distant from the include angle, as for the location of the soft magnetism material 3, the absolute value of surface inductive flux indicates maximum to be] small.

[0045]

Then, as shown in drawing 2 , the soft magnetism material 3 is made arrangement at the front-face side of the hard magnetism material 1. In drawing 3 , the inner circumference side location of soft magnetism material is arranged to the mid-position of the include angle from which the absolute value of surface inductive flux serves as max, and an include angle. At the include angle from which the absolute value of surface inductive flux serves as max, the easy magnetization direction has become in the direction of a path mostly, and near the soft magnetism material 3, the orientation of the hard magnetism material 1 is turned to in the direction near a hoop direction, as shown in drawing 3 . The absolute value of surface inductive flux becomes [the way which has arranged soft magnetism material to the inner circumference side rather than the case where the soft magnetism material 3 is arranged to the periphery side of drawing 2] high. When this has soft magnetism material near a front face, it is for the direction of magnetic flux or a field to influence in the direction which a magnet makes, and, as for effect, there is less arrangement of drawing 3 by the side of inner circumference to the value change of surface inductive flux. A ring magnet like drawing 3 has high surface inductive flux, induced voltage can be made high, and the permeability of the part of the soft magnetism material 3 becomes larger than 1.1, and magnetic reluctance is changing periodically in the hoop direction.

[0046]

(Example 5)

Drawing 5 is the sectional view of the ring magnet which prepared the soft magnetism section in the direction of a path of the pole edge of the polar anisotropy ring magnet of this invention. In drawing 5 , the hard magnetism material 1 is a ring configuration, and the direction 2 of orientation of the direction of an easy axis of the hard magnetism material 1 is changing periodically in the hoop direction. The soft magnetism material 3 plate-like [continuous] which came out to each front face by the side of the inner circumference of the hard magnetism material 1 and a periphery is arranged periodically in a hoop direction, and is the magnet of one as a whole.

[0047]

Iron powder is used for the soft magnetism material 3. SUTEARIN acid zinc is added about 1% as lubricant into 5-20-micrometer electrolytic iron powder, it inserts in mixed backward metal mold, pressing is carried out like the above-mentioned, and it forms in plate-like. The magnetic powder of the NdFeB system used in the example of drawing 3 is used for the hard magnetism material 1. Hard magnetism powder is inserted into the metal mold with which the Plastic solid of the soft

magnetism material 3 has been arranged. Then, it fabricates by the ** mosquito of 1 t/cm2 in the field of 8000Oe. The direction of a field is controlled by the coil by the side of the periphery of metal mold, or inner circumference along the direction 2 of orientation of the easy magnetization direction of the hard magnetism material 1 of drawing 5 , and a field is impressed at the time of shaping. The direction of a field with a coil is changed continuously [a hoop direction] within a ring, and periodically. In this metal mold, the slot on the crevice is established in an inside-and-outside periphery like an example 1, and an exact location is maintained for the Plastic solid of the soft magnetism material 3 at the time of pressing.

[0048]

In the orientation metal mold used in order to produce the magnet of drawing 5 , eight pairs of field impression coils were used, and the direction of a field has designed and applied the coil location so that it may become a sine wave mostly in a hoop direction. The current passed in a coil is 1x106 A/cm2, and is adding pulse current at the time of shaping. The field for carrying out orientation of the hard magnetism material 1 is added, and the c-axis of ****** which is the easy magnetization direction of Nd2Fe14B arranges after shaping along the direction 2 of orientation of the easy magnetization direction of the hard magnetism material 1 of drawing 5 . The c-axis of Nd2Fe14B has arranged after sintering and sintering and heat treatment along the direction 2 of orientation of the easy magnetization direction of the hard magnetism material 1 shown in drawing 5 .

[0049]

It considers as a ring configuration after the same sintering as an example 1, and heat treatment by processing by the diamond or the grinding stone, or processing by wire cut, Nd2Fe14B is magnetized using magnetization York (15 or more kOes of fields), and it becomes the ring magnet of drawing 5 .

[0050]

As for the configuration of the soft magnetism material 3, it is desirable to consider as the width of face of 1/2 or less hoop direction of the include angle of one pole, and to consider as 5 - 10% per pole to a hoop direction with 8 pole ring magnet of drawing 5 . If Nd2Fe14B is magnetized and the permeability of the ring magnet of drawing 5 is measured after processing, it will check that permeability is high 10% or more by the periphery side of the soft magnetism material 3. Moreover, with the ring magnet of drawing 5 , the amount of preferred orientation of the magnetic powder orientation of Nd2Fe14B can be made 90% or more, and induced voltage can be made high. This is because it can bring close to a sine wave and a high field is acquired in the location of hard magnetism material compared with the example of others [direction / of the magnetic path made by the soft magnetism material in an orientation forming cycle].

[0051]

(Example 6)

The ring magnet shown in above-mentioned drawing 2 , drawing 3 , and drawing 5 may consist of soft magnetism material 3 which is the parts which have bigger permeability than coercive force smaller than the coercive force which the hard magnetism material 1 made in the magnetic material near a polar anisotropy magnet shows, or the hard magnetism material 1. The direction 2 of orientation of the easy magnetization direction of the magnetic material of the hard magnetism material 1 is shown by the dotted line. In this case, although it is eight poles, if it is two or more poles, it is not necessary to limit especially a pole. The magnetic properties of the hard magnetism material 1 are magnetic materials with [residual magnetic flux density / (Br) / more than 0.6T] 5 or more kOes in coercive force (iHc), and use a rare-earth-elements [of a NdFeB system] (other rare earth elements, such as Dy, may be added to Nd) and Fe (Co may be added) and B (metalloid element other than B may be added), or SmCo system.

[0052]

At the creation process of a sintered magnet, after preparing the particle size distribution of magnetic powder raw material powder by grinding and the classification, orientation shaping called field orientation is using the process which arranges the sense of powder. If the direction and magnetic field strength of an orientation field are inadequate at this time, the sense of magnetic powder cannot fully be arranged, either. The orientation of the magnetic powder which

constitutes the ring magnet is detectable as angular dependence of X diffraction reinforcement, if the orientation of the center of a pole or the edge of a pole changes with poles. A pole edge is the location of the soft magnetism material 3 of drawing 5 here, and a pole core is a mid gear until it rotates from the location of the soft magnetism material 3 of drawing 5 and becomes the location of the following soft magnetism material.

[0053]

The dotted line of drawing 3 shows the direction of orientation (the same direction as the easy magnetization direction). The location of the above-mentioned pole edge is a location where this dotted line has become in the same direction (the direction of a path, and perpendicular direction) as a hoop direction. That is, the direction of orientation in a pole edge and a pole center position is mutually right-angled to the direction of a path, or a hoop direction. Although the dotted line of drawing 3 is roughly shown, it is difficult for the direction of the magnetic powder which constitutes an actual magnet for 100% of magnetic powder to make such a dotted line turn to. The magnitude of magnetic powder is several micrometers or less, and since it presses the particle size being distributed, and a configuration not being completely the same, either, and impressing an orientation field, it becomes difficult to arrange bearing in the direction of a field completely, after magnetic powder has contacted. In drawing 2 , drawing 3 , and drawing 5 , the dotted line shows the direction 2 of orientation of the easy magnetization direction of hard magnetism material, and the small ****** material 3 of coercive force is arranged at the pole edge. The small part of the **** mosquito made to arrange and form in the location of the soft magnetism material 3 is fabricated by the hard magnetism material 1 and one. The technique has the approach of arranging the Plastic solid of the soft magnetism material 3 before a sintering process in the location of the soft magnetism material 3, the technique of changing conditions, such as sintering temperature of the part of the soft magnetism material 3, in a sintering process, the technique of changing the magnetic properties of the part of the soft magnetism material 3 after sintering, etc.

[0054]

Before sintering, for arranging soft magnetism material into the part of the soft magnetism material 3, shaping is divided in two steps, after creating a Plastic solid, it sinters or making small the orientation field of the part of the soft magnetism material 3, and changing the magnetic properties of the neighborhood or the technique of impressing a high field only near the soft magnetism material 3 for a polar anisotropy magnet after orientation shaping, and changing magnetic properties is.

[0055]

To the technique of changing conditions, such as sintering temperature of the part of the soft magnetism material 3, in a sintering process, it is possible by carrying out whether only the part of the soft magnetism material 3 is higher than the usual sintering temperature, and it carries out to make coercive force small. It is possible to reduce coercive force by carrying out overheating quenching of the part of the soft magnetism material 3 after sintering and processing by the technique of changing the magnetic properties of the part of the soft magnetism material 3 after sintering. Even if a magnet is not the orientation of polar anisotropy, a magnetic-reluctance difference can be built by making a hoop direction arrange the part of the soft magnetism material 3 periodically, as shown in drawing in the case of a ring magnet with the radial orientation of drawing 1 .

[0056]

The ingredient used as the part of the soft magnetism material 3 can apply the magnetic material which has the soft magnetic characteristics of what made particle size of powder larger than a part besides single or more figures in the case of the NdFeB system, and made coercive force small, the thing made into the metastable structure near an amorphous substance or metallic glass by the presentation of a NdFeB system, the thing which made the powder of a NdFeB system mix the ferromagnetic material (alpha-Fe, Fe3B, Fe4N, Fe203 grade) from which magnetic properties differ, a Fe-Si alloy, etc.

[0057]

Drawing 6 is the diagram showing the wave of the surface **** consistency at the time of using

Fe-3%Si powder for the ring near polar anisotropy with a NdFeB system magnet at the soft magnetism material 3 by the side of inner circumference as shown in drawing 3 , and sintering by one. the used powder -- the anisotropy magnetic powder of $Nd_2Fe_{14}B$ -- it is -- coercive force (iHc) -- 15-25 -- kOe and Br are the powder which is 1.1-1.3T. Except for the location (location of the soft magnetism material 3 of drawing 3) of the Fe-3%Si powder in which soft magnetism is shown, orientation shaping is beforehand carried out only with NdFeB system magnetic powder, and pressing of the powder of the account soft magnetism material of Gokami is carried out to the location of the soft magnetism material 3 of drawing 3 . The rate of the direction volume of a path of the soft magnetism material in this case is 20%, and the width of face (location of the soft magnetism material 3 of drawing 3) of a hoop direction is about 5 times. As for this include angle, 1/2 or less [of the include angle (in the case of eight poles 45 degrees) of one pole] is desirable. A field required for orientation is 5000 or more Oes. The account Plastic solid of Gokami is put into a vacuum furnace, and heating sintering is carried out. Sintering temperature is 800-1200 degrees C. It is processed after sintering and a surface protective coat is formed if needed. Although drawing 3 shows the case of eight poles, even when it is which pole of two or more poles, it can be produced.

[0058]

In drawing 6 , an axis of ordinate is a relative value, and an axis of abscissa is an include angle. Magnet outer diameters are 30rnm(s), a bore is 20mm, and it is 20mm in height. A measuring point is 10mm in height by the side of a periphery, and measured the surface inductive flux of the direction of a path using the hall device. The wave of surface inductive flux is near and the waveform distortion is about 4% at a sine wave. Moreover, the peak value of surface inductive flux was the radial ring magnet produced in the same configuration, and more than an EQC.

[0059]

(Example 7)

Drawing 7 is the diagram showing the relation of the rate of the volume of soft magnetism material and the waveform distortion of surface inductive flux which examined the case where the rate of the volume of the soft magnetism material of the direction of a path was made [many] in an example 6. If the rate of the volume of soft magnetism material increases as shown in drawing 7 , the waveform distortion of surface inductive flux will increase. Moreover, although permeability also increases by the increment in the rate of the volume of soft magnetism material as shown in drawing 8 , even 20% is especially increasing rapidly.

[0060]

As for the waveform distortion of surface inductive flux increasing like drawing 7 , magnetic-properties degradation by diffusion between the powder of that the orientation of the powder of NdFeB which is the powder of hard magnetism material worsens, soft magnetism material, and hard magnetism material etc. is considered as a cause by existence of the powder of soft magnetism material. In order to secure reluctance torque and to control waveform distortion, it is desirable to make the rate of the direction volume of a path of soft magnetism material 5 - 50%. The permeability in the pole core of a ring magnet is 1.0-1.05 in this range. Although this makes powder of soft magnetism material the 100% of the directions of a path in drawing 5 , it is shown that a direction of the mixture of soft magnetism and hard magnetism is effective in the part of the soft magnetism material 3 at waveform distortion reduction.

[0061]

(Example 8)

Drawing 9 and drawing 10 are the perspective views of the rotator using the ring magnet manufactured in the examples 1-7. The adhesives of an organic system were used and the ring magnet 11 is pasted up in the center of shaft orientations of the rotation shaft 12. It differs [whether soft magnetism material is prepared in an inner circumference side according to the structure of a motor or it prepares in a periphery side, and]. Moreover, when also using the orientation of a polar anisotropy ring magnet for an outer rotor, it is made for magnetic flux to become strong at an inner circumference side. It is also possible to make the soft magnetism material 13 incline by shaft orientations, and to reduce cogging torque, as shown in drawing 10 . In the part (drum section) which pastes up the ring magnet 11, the rotation shaft 12 is made into

the path doubled with torque required for a motor, and serves as a major diameter most to the rotation shaft 12 of both sides. Pars intermedia is made into the thin path so that it may become lightweight, as it can have the path which can secure the reinforcement as a rotation shaft 12.
[0062]
In order to use mild steel, Fe alloy, aluminum alloy, Cu alloy, etc. for the rotation shaft 12 and to prevent oxidation and corrosion on the surface of a rotator, nickel plating, chemical conversion, etc. are performed.
[0063]
Drawing 11 is the sectional view of the motor which used the rotator of drawing 9 and drawing 10 . Since this motor can use the reluctance torque using the difference of magnetic reluctance, it can secure high torque in a low rotational frequency. Especially this motor is effective in the high Brit automobile equipped with the internal combustion engine of which high torque is required at a low speed, and the motor.
[0064]
[Effect of the Invention]
According to this invention, it can be possible to generate the difference of permeability in a hoop direction by the surface inductive flux of a ring magnet or an induced voltage wave raising near and the orientation based on [of a ring magnet] poles to a sine wave, and forming the powder of soft magnetism material in a hoop direction periodically, the waveform distortion of surface inductive flux can be small, the small rotator of cogging torque can be offered, and the reluctance torque in a low rotational frequency can be further applied to an available motor. Especially, an efficient motor can be manufactured and it can apply to conveyance of industrial use, the object for automobiles, a semiconductor device, etc., a positioning motor, etc.
[Brief Description of the Drawings]
[Drawing 1] The sectional view of the radial ring magnet which prepared the soft magnetism material of this invention in the hoop direction periodically at the pole edge periphery side.
[Drawing 2] The sectional view of the polar anisotropy ring magnet which prepared the soft magnetism material of this invention in the hoop direction periodically at the pole edge periphery side.
[Drawing 3] The sectional view of the polar anisotropy ring magnet which prepared the soft magnetism material of this invention in the hoop direction by the side of inner circumference periodically.
[Drawing 4] The sectional view of a polar anisotropy ring magnet.
[Drawing 5] The sectional view of the polar anisotropy ring magnet which prepared the soft magnetism material of this invention in the direction of a path of a pole edge.
[Drawing 6] The diagram showing the periphery side surface inductive flux of the ring magnet which prepared the soft magnetism section in the hoop direction periodically, and created it.
[Drawing 7] The diagram showing the relation between the waveform distortion of surface inductive flux, and the rate of the direction volume of a path of soft magnetism material.
[Drawing 8] The diagram showing the relation between the permeability of a ring magnet, and the rate of the direction volume of a path of soft magnetism material.
[Drawing 9] The perspective view of the rotator for motors which applied the ring magnet of this invention.
[Drawing 10] The perspective view of the rotator which applied the ring magnet of this invention which made soft magnetism material incline to shaft orientations.
[Drawing 11] The sectional view of the motor using the rotator of this invention.
[Description of Notations]
1 [-- Hard magnetism material (radial ring magnet), 11 / -- A polar anisotropy ring magnet, 12 / -- A rotation shaft, 14 / -- A stator, 15 / -- Ring magnet.] -- Hard magnetism material (polar anisotropy ring magnet), 2 -- 3 The direction of orientation of the easy magnetization direction of hard magnetism material, 13 -- Soft magnetism material, 4

[Translation done.]

DESCRIPTION OF DRAWINGS

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[Drawing 1] The sectional view of the radial ring magnet which prepared the soft magnetism material of this invention in the hoop direction periodically at the pole edge periphery side.
[Drawing 2] The sectional view of the polar anisotropy ring magnet which prepared the soft magnetism material of this invention in the hoop direction periodically at the pole edge periphery side.
[Drawing 3] The sectional view of the polar anisotropy ring magnet which prepared the soft magnetism material of this invention in the hoop direction by the side of inner circumference periodically.
[Drawing 4] The sectional view of a polar anisotropy ring magnet.
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[Drawing 7] The diagram showing the relation between the waveform distortion of surface inductive flux, and the rate of the direction volume of a path of soft magnetism material.
[Drawing 8] The diagram showing the relation between the permeability of a ring magnet, and the rate of the direction volume of a path of soft magnetism material.
[Drawing 9] The perspective view of the rotator for motors which applied the ring magnet of this invention.
[Drawing 10] The perspective view of the rotator which applied the ring magnet of this invention which made soft magnetism material incline to shaft orientations.
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[Description of Notations]
1 [-- Hard magnetism material (radial ring magnet), 11 / -- A polar anisotropy ring magnet, 12 / -- A rotation shaft, 14 / -- A stator, 15 / -- Ring magnet.] -- Hard magnetism material (polar anisotropy ring magnet), 2 -- 3 The direction of orientation of the easy magnetization direction of hard magnetism material, 13 -- Soft magnetism material, 4

[Translation done.]

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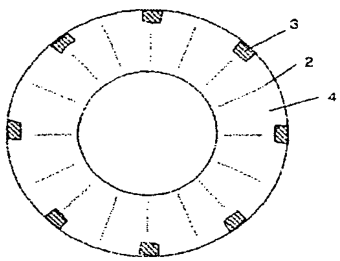
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

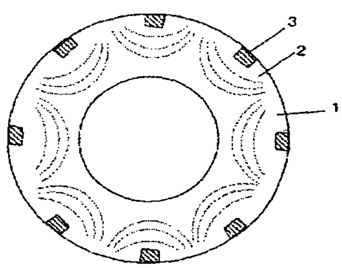
[Drawing 1]

図1



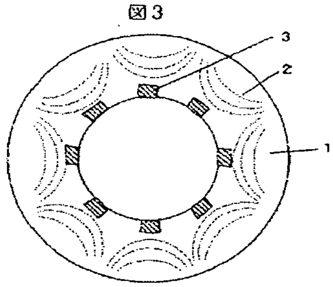
[Drawing 2]

図2



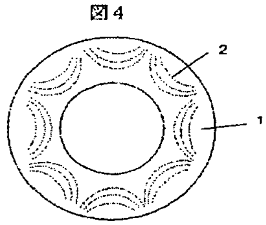
[Drawing 3]

図3



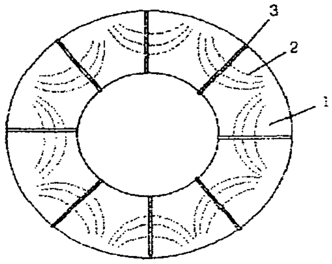
[Drawing 4]

図4



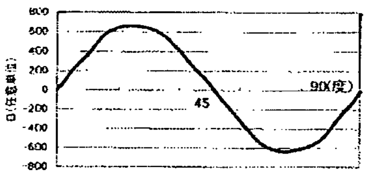
[Drawing 5]

図5



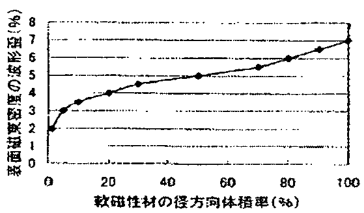
[Drawing 6]

図6



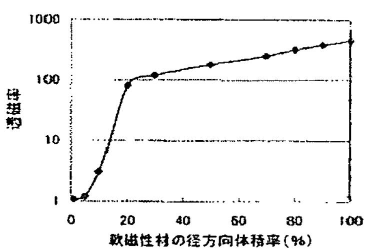
[Drawing 7]

図7



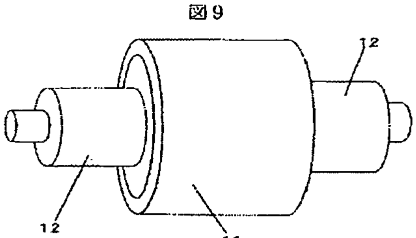
[Drawing 8]

図8

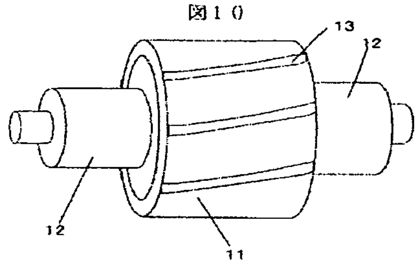


[Drawing 9]

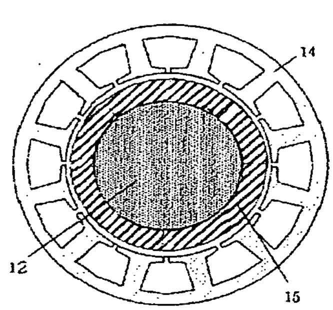
図9



[Drawing 10]



[Drawing 11]



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(71) 出願人 000005108
株式会社日立製作所
東京都千代田区神田駿河台四丁目６番地
(71) 出願人 000005083
日立金属株式会社
東京都港区芝浦一丁目２番１号
(74) 代理人 100074631
弁理士　高田　幸彦
(72) 発明者 小室　又洋
茨城県日立市大みか町七丁目１番１号
株式会社日立製作所日立研究
所内

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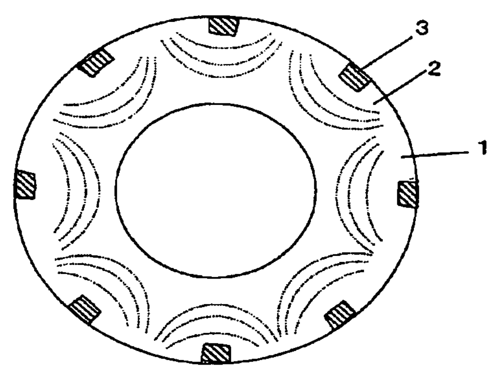
(54) 【発明の名称】 リング磁石とその製造法及びそれを用いた回転子並びにモータ

(57) 【要約】
【課題】本発明の目的は、リング磁石の周方向に磁気抵抗の差をもたせ、磁気抵抗の差を利用したリラクタンストルクと極異方性磁石の低コギングトルクを両立したリング磁石とその製造法及びそれを用いた回転子並びに回転機を提供することにある。
【解決手段】本発明は、容易磁化方向が周方向又は径方向で周期的に変化したリング状硬質磁性材内に複数個の軟磁性材が周方向で一定の間隔で一体に形成されていることを特徴とするリング磁石にある。更に、本発明は、リング状に配置された硬質磁性材粉末中の周方向に一定の間隔で複数個の軟磁性材を配置する複合体の形成工程と、前記複合体を磁界中で配向させながら加圧成形体を形成する加圧成形工程と、前記加圧成形体を焼結させる焼結工程とを有することを特徴とするリング磁石の製造法にある。
【選択図】　図２

図２



【特許請求の範囲】
【請求項１】
容易磁化方向が周方向又は径方向で周期的に変化したリング状硬質磁性材内に複数個の軟磁性材が周方向で一定の間隔で一体に形成されていることを特徴とするリング磁石。
【請求項２】
容易磁化方向が周方向又は径方向で周期的に変化したリング状硬質磁性材の外周側又は内周側の少なくとも一方に複数個の軟磁性材が周方向で一定の間隔で埋め込まれ、一体に形成されていることを特徴とするリング磁石。
【請求項３】
容易磁化方向が周方向で正弦波状に周期的に変化したリング状硬質磁性材の外周側又は内周側の少なくとも一方に複数個の軟磁性材が周方向で一定の間隔で埋め込まれ、一体に形成されていることを特徴とするリング磁石。
【請求項４】
容易磁化方向が周方向で正弦波状に周期的に変化したリング状硬質磁性材内に内周側から外周側にかけて連続した複数個の軟磁性材が周方向で一定の間隔で一体に形成されていることを特徴とするリング磁石。
【請求項５】
請求項１～４のいずれかにおいて、前記硬質磁性材と軟磁性材とは焼結によって一体に形成されていることを特徴とするリング磁石。
【請求項６】
請求項１～５のいずれかにおいて、前記硬質磁性材と軟磁性材とは、磁界中で加圧成形後、前記焼結されていることを特徴とするリング磁石。
【請求項７】
請求項１～６のいずれかにおいて、前記軟磁性材は前記硬質磁性材の周方向における容易磁化方向が前記周方向に向いた位置に形成されていることを特徴とするリング磁石。
【請求項８】
リング状に配置された硬質磁性材粉末中の周方向に一定の間隔で複数個の軟磁性材を配置する複合体の形成工程と、前記複合体を磁界中で配向させながら加圧成形体を形成する加圧成形工程と、前記加圧成形体を焼結させる焼結工程とを有することを特徴とするリング磁石の製造法。
【請求項９】
リング状に配置された硬質磁性材粉末中の外周側又は内周側の少なくとも一方に複数個の軟磁性材を周方向に一定の間隔で配置する複合体の形成工程と、前記複合体を磁界中で配向させながら加圧成形体を形成する加圧成形工程と、前記加圧成形体を焼結させる焼結工程とを有することを特徴とするリング磁石の製造法。
【請求項１０】
リング状に配置された硬質磁性材粉末中の一部に内周側から外周側にかけて連続した複数個の軟磁性材を周方向に一定の間隔で配置する複合体の形成工程と、前記複合体を磁界中で配向させながら加圧成形体を形成する加圧成形工程と、前記加圧成形体を焼結させる焼結工程とを有することを特徴とするリング磁石の製造法。
【請求項１１】
請求項８～１０のいずれかにおいて、前記リング状の硬質磁性材の容易磁化方向が周方向又は径方向で周期的に変化するように前記磁界方向を調整することを特徴とするリング磁石の製造法。
【請求項１２】
請求項８～１１のいずれかにおいて、前記軟磁性材は、軟磁性材粉を径方向になる方向の磁場中又は無磁場中にて加圧成形されたものであることを特徴とするリング磁石の製造法。
【請求項１３】
請求項８～１２のいずれかにおいて、前記軟磁性材を、前記硬質磁性材の容易磁化方向が

前記周方向に向いた位置に配置することを特徴とするリング磁石の製造法。
【請求項１４】
シャフトの外周にリング状磁石を有する回転子において、前記リング磁石が、請求項１～７のいずれかに記載のリング磁石からなることを特徴とする回転子。
【請求項１５】
シャフトの外周にリング状磁石を有する回転子において、前記リング磁石が、請求項８～１３のいずれかに記載のリング磁石の製造法によって形成されたリング磁石からなることを特徴とする回転子。
【請求項１６】
固定子と、該固定子内を回転する回転子とを有する回転機において、前記回転子が請求項１４又は１５に記載の回転子からなることを特徴とする回転機。
【請求項１７】
請求項１６において、定格トルクに対してコギングトルクが５％以下であることを特徴とする回転機。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】
本発明は、新規なリング磁石とその製造法及びそれを用いた回転子並びに回転機に関する。
【０００２】
【従来の技術】
【特許文献１】特開２０００－２６９０６２号公報
【特許文献２】特開２０００－１９５７１４号公報
従来のリング磁石において、容易磁化方向が周方向で連続的に変化した異方性
磁石については、
【特許文献１】、
【特許文献２】に記載されている。これらの公知例では、磁粉成形する工程においてコイル等による磁界によって磁粉を磁界の方向に配向させ、磁粉の配向方向に容易磁化方向がそろっている。磁粉の配向、成形後に焼結させ、焼結後の磁石は容易磁化方向が周方向で変化し、高い磁気特性をもった極異方性磁石を作成することが記載されている。
【０００３】
【発明が解決しようとする課題】
従来の技術では、磁気抵抗の差を利用したリラクタンストルクと極異方性磁石の低コギングトルクを両立したリング磁石は示されていない。又、リラクタンストルク確保のために磁気特性の異なる磁性材の粉を一体で成形したリング磁石の周方向に周期的に配列させることは示されていない。
【０００４】
発明者らは、リラクタンストルクを利用できれば低回転数におけるトルクを確保することが可能であり、低回転数で大きなトルクが必要なモータへ応用することができることから、リラクタンストルクを利用する構造を検討した結果、磁気的に硬質なリングの周方向に軟質な部分を設けることを見出した。又、発明者らは、このようなリラクタンストルクを生み出すには、磁石を周方向に分割して磁石と磁石の間に軟磁性材を挿入させることで実現可能であるが、磁石の加工精度の確保が困難であること、磁石の接着工程が必要なこと、回転時の磁石保持、表面磁束密度のばらつき増大などの問題があることを見出した。
【０００５】
更に、磁石を極ごとに分割する場合、１極ごとの形状ばらつきにより、表面磁束密度波形が変化する。特に磁石径がばらつくと、固定子のティース先端部における磁束が極ごとに異なる。磁石と軟磁性材の接着は回転子の強度低下をまねいたり、接着部の非磁性ギャップによる磁束の不均一性増大に繋がる。
【０００６】

本発明の目的は、リング磁石の周方向に磁気抵抗の差をもたせ、磁気抵抗の差を利用したリラクタンストルクと極異方性磁石の低コギングトルクを両立したリング磁石とその製造法及びそれを用いた回転子並びに回転機を提供することにある。
【０００７】
【課題を解決するための手段】
本発明は、磁気抵抗の差を利用したリラクタンストルクと極異方性磁石の低コギングトルクを両立させたリング磁石にある。リラクタンストルクを利用できれば低回転数におけるトルクを確保することが可能となり、低回転数でトルクが必要なモータへ応用することができる。リラクタンストルクを利用するには、磁気的に硬質なリングの周方向に軟質な部分を設ける必要がある。このようなリラクタンストルクを生み出すには、磁石を周方向に分割して磁石と磁石の間に精度高く、容易に軟磁性材を挿入させることで実現でき、回転時の磁石保持、表面磁束密度のばらつきなどの問題が解決できるものである。
【０００８】
本発明は、容易磁化方向が周方向又は径方向で周期的に変化したリング状硬質磁性材内に複数個の軟磁性材が周方向で一定の間隔で一体に形成されていることを特徴とするリング磁石にある。更に、本発明は、以下の要件を有する。
【０００９】
容易磁化方向が周方向又は径方向で周期的に変化したリング状硬質磁性材の外周側又は内周側の少なくとも一方に複数個の軟磁性材が周方向で一定の間隔で埋め込まれ、一体に形成されていることを特徴とするリング磁石。
【００１０】
容易磁化方向が周方向で正弦波状に周期的に変化したリング状硬質磁性材の外周側又は内周側の少なくとも一方に複数個の軟磁性材が周方向で一定の間隔で埋め込まれ、一体に形成されていることを特徴とするリング磁石。
【００１１】
容易磁化方向が周方向で正弦波状に周期的に変化したリング状硬質磁性材内に内周側から外周側にかけて連続した複数個の軟磁性材が周方向で一定の間隔で一体に形成されていることを特徴とするリング磁石。
【００１２】
本発明のリング磁石は、前記硬質磁性材と軟磁性材とが焼結によって一体に形成されていること、前記硬質磁性材と軟磁性材とが磁界中で加圧成形後、前記焼結されていること、前記軟磁性材は前記硬質磁性材の周方向における容易磁化方向が前記周方向に向いた位置に形成されていることが好ましい。
【００１３】
本発明は、リング状に配置された硬質磁性材粉末中の周方向に一定の間隔で複数個の軟磁性材を配置する複合体の形成工程と、前記複合体を磁界中で配向させながら加圧成形体を形成する加圧成形工程と、前記加圧成形体を焼結させる焼結工程とを有することを特徴とするリング磁石の製造法にある。
【００１４】
即ち、本発明は、硬質磁性材の粉末を磁界によって配向させる工程と、配向させた粉末を焼結させる工程を経て、軟磁気特性を示す部分が硬質磁性材と一体で成形し、軟磁気特性を示す部分の配置を周方向で周期的にしたものである。
【００１５】
また、本発明は、前記リング状に配置された硬質磁性材粉末中の外周側あるいは内周側の一部に軟磁性材の粉末から成形焼結した透磁率の高い部分を整列させて成形したものである。
【００１６】
または、前記リングの外周側あるいは内周側の一部に軟磁性材の粉末から成形、焼結した軟磁気特性を示す部分が周方向で一定の周期で整列させて成形されるものである。
【００１７】

本発明は、硬質磁性材及び軟磁性材の粉末を使用し、磁界によってこれらの粉末を配向させる工程と配向させた粉末を焼結させる工程を有し、リング磁石を形成している硬質磁性材の容易磁化方向を周方向で正弦波状に周期的に変化させ、前記リングの内周側でかつ硬質磁性材の容易磁方向がほぼ周方向に向いた周方向角度位置に軟磁性材からなる透磁率の高い部分があり、軟磁気特性を示す部分が周方向で一定の周期で整列させたものである。

【００１８】

本発明は、硬質磁性材及び軟磁性材の粉末を磁界によって配向させる工程と、配向させた粉末を焼結させる工程を経て作製されたリング磁石の硬質磁性材の容易磁化方向を周方向で正弦波状に周期的に変化させ、前記リングの硬質磁性材の容易磁化方向がほぼ周方向に向いた位置の近傍に内周側から外周側に連続した軟磁性材からなる透磁率の高い部分を設け、軟磁気特性を示す部分が周方向で一定の周期で整列されたものである。

【００１９】

本発明は、硬質磁性材の粉末を磁界によって配向させる工程と、配向させた粉末を焼結させる工程を経て作製されるリング状磁石において、軟磁気特性を示す部分が硬質磁性材と一体で成形し、配向方向に近い方向に加えた外部磁界によってリング状磁石を着磁後、表面磁束密度の波形がほぼ正弦波になっているものである。

【００２０】

前記リング状の硬質磁性材の容易磁化方向が周方向又は径方向で周期的に変化するように前記磁界方向を調整すること、前記軟磁性材は、軟磁性材粉を径方向になる方向の磁場中又は無磁場中にて加圧成形されたものであること、前記軟磁性材を、前記硬質磁性材の容易磁化方向が前記周方向に向いた位置に配置することが好ましい。

【００２１】

更に、本発明は、シャフトの外周にリング状磁石を有する回転子において、前記リング磁石が前述に記載のリング磁石からなること、又前述に記載の製造法によって形成されたリング磁石からなることを特徴とする。

【００２２】

又、本発明は、固定子と、該固定子内を回転する回転子とを有する回転機において、前記回転子が前述に記載の回転子からなることを特徴とし、特にモータにおいて定格トルクに対してコギングトルクが５％以下と小さく、高い誘起電圧を有しているものである。

【００２３】

【発明の実施の形態】

（実施例１）

図１は、本発明のラジアルリング磁石の極端部外周側に周方向に周期的に軟磁性部３を設けたリング磁石の断面図である。硬質磁性材４の容易磁化方向の配向方向２を点線で示している。硬質磁性材４の容易磁化方向の配向方向２は径方向であり、配向方向と垂直方向が困難軸方向である。

【００２４】

硬質磁性材４は、少なくとも１種類の希土類金属、ＦｅあるいはＣｏ、及びＢあるいはＮの元素からなる化合物を含んでおり、特にＮｄＦｅＢ系、ＮｄＤｙＦｅＢ系、ＮｄＦｅＣｏＢ系、ＳｍＣｏ系、ＳｍＣｏＦｅ系、ＳｍＦｅＮ系、ＳｍＣｏＺｒＮ系が残留磁束密度が高いので、誘起電圧を高くできる。これらの硬質磁性材の粉末を組成調整、粒度分布調整後、前記粉末を磁界によって磁石として磁束を特定の方向に配向して用いられる。また、軟磁性材３はリング磁石の外周部に極数と同じ数で配置している。軟磁性材３はＦｅ合金が透磁率が高くなるために最適であり、Ｆｅ－Ｓｉ、Ｆｅ－Ａｌ、Ｆｅ－Ｂ、Ｆｅ－Ｃなどが良い。

【００２５】

配向から焼結工程について以下に説明する。初めに軟磁性材３を四角形状の長尺の成形金型を用いて１～１０ｔ／ｃｍ^{2}以下の圧力で成形する。成形中の磁界は無磁場あるいはラジアル方向となる方向に磁界を印加させる。上記Ｆｅ合金粉には潤滑材としてステアリン酸を約１％添加し、よく混合した後に成形する。軟磁性材の粉の成形体を周方向にほぼ等

間隔で配向金型の外周側に配置する。軟磁性材３は、その長手方向に対して垂直な断面形状は他に丸、三角、楕円など単純なものが良い。

【００２６】

次に、軟磁性材３の成形体を２重円筒状の金型内の外周側に配置し、上記硬質磁性材４の粉をその金型内に注入する。金型内の外周側には、軟磁性材３の成形体が一部挿入できるようにそれと長さと幅が同一形状の凹部が設けられ、そこにはめ込まれ、硬質磁性材４の粉の注入時及び加圧成形時に動かないようにする。又、金型の長さは、軟磁性材３の成形体より長くなっており、加圧成形後に軟磁性材３の成形体と同じ長さになるように大きく、その加圧側はストレートに設けられる。コイルあるいは磁石からの磁界によって硬質磁性材４の粉の配向をラジアル方向に向けて加圧成形する。成形圧力は１～１０ｔ／ｃｍ^{2}である。１～３μｍの粒径のＮｄＦｅＣｏＢ系の粉を使用すれば、８０００Ｏｅの磁界を印加することにより、図５の硬質磁性材４の容易磁化方向の配向方向２に示す径方向あるいはラジアル方向に配向させることができる。この時の硬質磁性材４の粉の配向度は８０％以上である。本金型によって軟磁性材３の成形体の正確な配置が得られる。

【００２７】

このように加圧成形した粉を真空中（真空度１×１０$^{-2}$Ｐａ）で焼結させる。まず、４００～５００℃で予備焼結をする。この時潤滑剤が蒸発する。焼結温度は８００℃以上１２００℃以下（５時間）であり、Ｎｄ$_2$（Ｆｅ、Ｃｏ）$_{14}$Ｂ（主相）及びＮｄ$_2$（Ｆｅ、Ｃｏ）$_{14}$ＢよりもＮｄ量が多い相（Ｎｄリッチ相）であるＮｄＦｅ$_4$Ｂ$_4$が生成する。このＮｄリッチ相がバインダの役割となり軟磁性材３と硬質磁性材との界面も焼結される。又、焼結時に軟磁性材３の成形体の正確な配置によって焼結後も１極ごとの形状のバラツキの少ないリング磁石が得られる。

【００２８】

焼結後、保磁力を増加させるために再度６００℃以上１０００℃以下（５時間）の温度で熱処理をする。熱処理後の主相の粒径は２～１５μｍである。熱処理後に外周内外周を加工し、図１のようなリング磁石になる。このリング磁石は８極であり、外周側に極数と同じ数で軟磁性材３が配置されている。一つの軟磁性材の位置は、周方向に１極の角度の５～１０％である。径方向には３～１０％の厚さで作製している。

【００２９】

（実施例２）

図２は、本発明の極異方性リング磁石の極端部外周側に周方向に周期的に軟磁性材３を設けたリング磁石の断面図である。図２では硬質磁性材１はリング形状であり、硬質磁性材１の磁化容易軸方向２が周方向で周期的に変化している。外周側に同一周面で軟磁性材３の表面が出るように周期的に軟磁性材３が配置され、全体として一体の磁石である。硬質磁性材１の材質は、実施例１と同様の物が用いられる。

【００３０】

軟磁性材３には鉄粉を使用する。粒径５～２０μｍの電解鉄粉に潤滑材としてステアリン酸亜鉛を約１％添加して混合後金型に挿入し、実施例１と同様に加圧成形し、四角形状の長尺形状とする。硬質磁性材１にはＮｄＦｅＢ系の磁性粉を用いている。ＮｄＦｅＢ系磁性粉の粒径は３～１５μｍである。エネルギー積を高くするためには平均粒径３～５μｍの単結晶粉を使用する。この磁性粉を軟磁性材２の成形体が外周側に配置された金型の中に挿入する。その後、８０００Ｏｅの磁界中で１ｔ／ｃｍ^{2}の圧力で成形する。金型の外周側あるいは内周側に配置したコイルにより図２の硬質磁性材の容易磁化方向２に沿って磁界方向を制御して成形時に磁界を印加する。コイルによる磁界方向をリング内で周方向に連続的かつ周期的に変化させる。

【００３１】

図２では８対の磁界印加コイルを磁性粉挿入部の外周側あるいは内周側に極数に応じて配置されたものを使用し、磁界方向は周方向にほぼ正弦波になるようにコイル位置を設計して、金型に適用している。コイルに流す電流は１×１０^{6}Ａ／ｃｍ^{2}であり、パルス電流を成形時に加えている。硬質磁性材を配向させるための磁界を加えて成形後、Ｎｄ$_2$Ｆｅ

$_{14}$Bの容易磁化方向である正方晶のc軸が図4の硬質磁性材の容易磁化方向の配向方向2に沿って配列する。実施例1と同様に焼結後や焼結、熱処理後も、$Nd_2Fe_{14}B$のc軸は図4に示す硬質磁性材の容易磁化方向2に沿って配列している。焼結、熱処理後にダイヤモンドや砥石による加工あるいはワイヤーカットによる加工によりリング形状とし、着磁ヨークを用いて$Nd_2Fe_{14}B$を着磁（磁界15kOe以上）し、図2のリング磁石となり、リング磁石は周期的に周方向の透磁率が変化する。

【0032】

軟磁性材3の形状は8極リング磁石では、1極の角度の1／2以下の周方向の幅で、径方向は外周側の位置で径方向厚さの1／2以下とし、実施例1と同様とするのが好ましい。径方向の軟磁性材3の体積率が1／2以上になると表面磁束密度の波形歪が5％以上になり、表面磁束密度のピーク値も低下する。また、周方向の軟磁性材3が1／2以上になると、表面磁束密度の波形歪が著しく増加する。

【0033】

（実施例3）

本実施例は、実施例2の硬質磁性材1として$Nd_2Fe_{14}B$に代えてSmCo系を用いたもので、SmCo系の場合には、焼結温度よりも低い温度で溶体化処理により均一化させる。Sm_2Co_{17}の粉を軟磁性材成形体が実施例2と同様に配置された金型に挿入して、配向磁界を印加しながら加圧成形する。軟磁性材3には電解Fe粉を用いる。電解Fe粉の成形圧力は約5t/cm^2である。Sm_2Co_{17}粉成形形時の磁界は7000Oe以上であり、c軸を磁界方向に配向させる。成形時の圧力は1～10t/cm^2である。成形体を真空加熱炉内で実施例1と同様に予備焼結し、更に1000～1200℃で焼結後、700～900℃で熱処理する。焼結時の雰囲気は水素、不活性ガスあるいは真空である。Coの一部をCuに変えた組成にすることにより、10kOeを超える保磁力でエネルギー積（Bhmax）が90kJ/m^3のリング磁石を得ることができる。

【0034】

焼結後のSm_2Co_{17}の配向は図2に示すように周方向で周期的かつ連続的に変化する。このような配向に容易磁化方向が沿うように配向成形に使用する配向ヨークのコイルあるいは磁石の位置を設計する。コイルあるいは磁石はリング状の磁性粉挿入部の外周側あるいは内周側に極数に応じて配置されたものを使用している。硬質磁性材3の形状は図2の8極リング磁石では、1極の角度の1／2以下の周方向の幅で、径方向は外周側の位置で径方向厚さの1／2以下とし、実施例1と同様とするのが好ましい。径方向の軟磁性材の体積率が1／2以上になると表面磁束密度の波形歪が5％以上になり、表面磁束密度のピーク値も低下する。

【0035】

また、周方向の軟磁性材が1／2以上になると、表面磁束密度の波形歪が著しく増加する。加工後にSm_2Co_{17}を着磁して図2のリング磁石の透磁率を測定すると透磁率が軟磁性材3の外周側で5％以上高くなっていることを確認している。

【0036】

また、図2のような硬質磁性材2の配向が周方向で連続的に変化する場合は、同一形状で同一磁性材料の場合、表面磁束密度が図1よりも高い。周方向に磁化容易軸方向が変化しているリング磁石の場合、軟磁性材3の位置は表面磁束密度の絶対値が最大値を示す角度から離れたほうが、表面磁束密度の波形歪が小さくなる。そこで図2に示すような軟磁性材3の配置にする。図2では、軟磁性材の位置は表面磁束密度の絶対値が最大となる角度と角度の中間位置に配置している。表面磁束密度の絶対値が最大となる角度では、容易磁化方向がほぼ径方向になっており、軟磁性材3の付近では硬質磁性材の配向は図2に示すように周方向に近い方向に向いている。このようなリング磁石は、表面磁束密度が高く、誘起電圧を高くすることができ、かつ軟磁性材3の部分の透磁率が1．1よりも大きくなるので、磁気抵抗が周方向で周期的に変化している。

【0037】

本実施例の硬質磁性材1のSmCo系を実施例1に用いた場合においても同様の効果を得

ることができる。

【００３８】

（実施例４）

図３は、本発明の極異方性リング磁石の内周側に軟磁性部を周方向に周期的に設けたリング磁石の断面図である。図３では硬質磁性材１はリング形状であり、硬質磁性材１の磁化容易軸方向の配向方向２が周方向で周期的に変化している。内周側表面に軟磁性材３の表面がでるように周期的に軟磁性材３が配置され、全体として一体の磁石である。

【００３９】

軟磁性材３には鉄粉を使用する。５～２０μｍの電解鉄粉に潤滑剤としてステアリン酸亜鉛を約１％添加して混合後金型に挿入する。硬質磁性材１にはＮｄＦｅＢ系の磁性粉を用いている。ＮｄＦｅＢ系磁粉は、$Nd_2Fe_{14}B$、$(M,Dy)_2Fe_{14}B$、$(Nd,Dy)_{15}Fe_{77}B_7Al_1$、$(Nd,Dy)_2(Fe,Co)_{14}B$を要求される磁気特性、製造コスト、使用環境に応じて選択しているが軟磁性材３を配置させて得られる透磁率の周方向における周期的変化を生み出すためには、上記ＮｄＦｅＢ系、ＳｍＣｏ系のいずれでも良い。金型は、実施例１の外周を内周と同様の構造にしたものである。それによって形状にバラツキの少ないリング磁石が得られる。

【００４０】

使用したＮｄＦｅＢ系磁性粉の粒径は３～１５μｍである。エネルギー積を高くするためには平均粒径３５μｍの単結晶粉を使用する。この磁性粉を軟磁性材の成形体が配置された金型の中に挿入する。その後、８０００Ｏｅの磁界中で$1t/cm^2$の圧力で成形する。金型の外周側あるいは内周側のコイルにより図３の硬質磁性林の容易磁化方向２に沿って磁界方向を制御して成形時に磁界を印加する。コイルによる磁界方向をリング内で周方向に連続的かつ周期的に変化させる。

【００４１】

図３では８対の磁界印加コイルを使用し、磁界方向は周方向にほぼ正弦波になるようにコイル位置を設計して、金型に適用している。コイルに流す電流は$1\times10^6A/cm^2$であり、パルス電流を成形時に加えている。硬質磁性材を配向させるための磁界を加えて成形後、$Nd_2Fe_{14}B$の容易磁化方向である正方晶のｃ軸が図３の硬質磁性材の容易磁化方向２に沿ってほぼ配列する。実施例１と同様に焼結後や焼結、熱処理後も$Nd_2Fe_{14}B$のｃ軸は図３に示す硬質磁性材の容易磁化方向２に沿って配列している。焼結、熱処理後にダイヤモンドや砥石による加工あるいはワイヤーカットによる加工によりリング形状とし、着磁ヨークを用いて$Nd_2Fe_{14}B$を着磁（磁界１５ｋＯｅ以上）し、図３のリング磁石となる。

【００４２】

軟磁性材３の形状は図３の８極リング磁石では、１極の角度の１／２以下の周方向の幅で、径方向は外周側の位置で径方向厚さの１／２以下である。径方向の軟磁性材３の体積率が１／２以上になると表面磁束密度の波形歪が５％以上になる。実施例１と同様とするのが好ましい。

【００４３】

軟磁性材３を配置させずに硬質磁性材１のみでリング磁石を作製すると図４のようになる。図４の硬質磁性材１の配向は周方向に連続かつ周期的に繰り返されており、硬質磁性材の容易磁化方向の配向方向２は図４に示すように８回繰り返されている。図４のようなリング磁石の外周側の透磁率は周方向でほとんど変化しない。そのため、リラクタンストルクを活用することは困難である。

【００４４】

これに対し、図３の構成の焼結体を得るためにリング形状に加工し、$Nd_2Fe_{14}B$を着磁してのリング磁石の透磁率を測定すると透磁率が軟磁性材３の外周側で２％以上高い。また、図３のような硬質磁性材２の配向が周方向で連続的に変化する場合は、同一形状で同一磁性材料の場合、表面磁束密度が図１よりも高い。周方向に磁化容易軸方向が変化しているリング磁石の場合、軟磁性材３の位置は表面磁束密度の絶対値が最大値を示す角

度から離れたほうが、表面磁束密度の波形歪が小さくなる。

【００４５】

そこで図２に示すように軟磁性材３を硬質磁性材１の表面側に配置にする。図３では、軟磁性材の内周側位置は表面磁束密度の絶対値が最大となる角度と角度の中間位置に配置している。表面磁束密度の絶対値が最大となる角度では、容易磁化方向がほぼ径方向になっており、軟磁性材３の付近では硬質磁性材１の配向は図３に示すように周方向に近い方向に向いている。図２の外周側に軟磁性材３を配置する場合よりも内周側に軟磁性材を配置したほうが表面磁束密度の絶対値が高くなる。これは表面付近に軟磁性材があると磁束あるいは磁界の方向が磁石の作る方向に影響するためであり、内周側の図３の配置のほうが表面磁束密度の値の変化に対して影響が少ない。図３のようなリング磁石は、表面磁束密度が高く、誘起電圧を高くすることができ、かつ軟磁性材３の部分の透磁率が１．１よりも大きくなり、磁気抵抗が周方向で周期的に変化している。

【００４６】

（実施例５）

図５は、本発明の極異方性リング磁石の極端部の径方向に軟磁性部を設けたリング磁石の断面図である。図５では硬質磁性材１はリング形状であり、硬質磁性材１の磁化容易軸方向の配向方向２が周方向で周期的に変化している。硬質磁性材１の内周側と外周側の各々の表面に出た連続した平板状の軟磁性材３が周方向に周期的に配置され、全体として一体の磁石である。

【００４７】

軟磁性材３には鉄粉を使用する。５～２０μｍの電解鉄粉に潤滑材としてステァリン酸亜鉛を約１％添加して混合後金型に挿入し、前述と同様に加圧成形され、平板状に形成する。硬質磁性材１には図３の実施例で使用したＮｄＦｅＢ系の磁性粉を用いている。硬質磁性粉を軟磁性材３の成形体が配置された金型の中に挿入する。その後、８０００Ｏｅの磁界中で１ｔ／ｃｍ^{2}の圧力で成形する。金型の外周側あるいは内周側のコイルにより図５の硬質磁性材１の容易磁化方向の配向方向２に沿って磁界方向を制御して成形時に磁界を印加する。コイルによる磁界方向をリング内で周方向に連続的かつ周期的に変化させる。本金型においては、内外周に実施例１と同様に凹部の溝が設けられ、軟磁性材３の成形体が加圧成形時において正確な位置が保たれる。

【００４８】

図５の磁石を作製するために用いた配向金型では８対の磁界印加コイルを使用し、磁界方向は周方向にほぼ正弦波になるようにコイル位置を設計して適用している。コイルに流す電流は１×１０^{6}Ａ／ｃｍ^{2}であり、パルス電流を成形時に加えている。硬質磁性材１を配向させるための磁界を加えて成形後、$Nd_2Fe_{14}B$の容易磁化方向である正方晶のｃ軸が図５の硬質磁性材１の容易磁化方向の配向方向２に沿って配列する。焼結後や焼結、熱処理後も$Nd_2Fe_{14}B$のｃ軸は図５に示す硬質磁性材１の容易磁化方向の配向方向２に沿って配列している。

【００４９】

実施例１と同様の焼結、熱処理後にダイヤモンドや砥石による加工あるいはワイヤーカットによる加工によりリング形状とし、着磁ヨークを用いて$Nd_2Fe_{14}B$を着磁（磁界１５ｋＯｅ以上）し、図５のリング磁石となる。

【００５０】

軟磁性材３の形状は図５の８極リング磁石では、１極の角度の１／２以下の周方向の幅とし、周方向に対して１極当たり５～１０％とするのが好ましい。加工後に$Nd_2Fe_{14}B$を着磁して図５のリング磁石の透磁率を測定すると透磁率が軟磁性材３の外周側で１０％以上高くなっていることを確認している。また、図５のリング磁石では$Nd_2Fe_{14}B$の磁粉配向の配向度を９０％以上にすることができ、誘起電圧を高くすることができる。これは、配向成形工程における軟磁性材により作られる磁路の方向が硬質磁性材の位置で他の例に比べて正弦波に近づけることができ、かつ高い磁界が得られるためである。

【００５１】

（実施例６）
前述の図２、図３、図５に示すリング磁石は極異方性磁石に近い磁性材でできた硬質磁性材１の示す保磁力よりも小さな保磁力あるいは硬質磁性材１よりも大きな透磁率を有する部分である軟磁性材３から構成されても良い。硬質磁性材１の磁性材の容易磁化方向の配向方向２は点線で示される。この場合８極になっているが２極以上であれば極数は特に限定する必要はない。硬質磁性材１の磁気特性は残留磁束密度（Ｂｒ）が０．６Ｔ以上、保磁力（ｉＨｃ）が５ｋＯｅ以上を有した磁性材料であり、ＮｄＦｅＢ系の希土類元素（ＮｄにＤｙなど他の希土類元素を添加する場合もある）及びＦｅ（Ｃｏを添加する場合もある）、Ｂ（Ｂ以外の半金属元素を添加する場合もある）あるいはＳｍＣｏ系を使用する。

【００５２】
焼結磁石の作成工程では、磁粉原料粉の粒度分布を粉砕と分級により整えた後に磁界配向という配向成形が粉の向きを揃える工程を使用している。このとき、配向磁界の方向や磁界強度が不十分になっていると、磁粉の向きも十分に揃えることができない。リング磁石を構成している磁粉の配向は、極数により極の中央あるいは極の端部の配向が異なれば、Ｘ線回折強度の角度依存性として検出できる。ここで、極端部というのは、図５の軟磁性材３の位置であり、極中心は図５の軟磁性材３の位置から回転して次の軟磁性材の位置になるまでの中央位置である。

【００５３】
図３の点線は配向方向（容易磁化方向と同じ方向）を示したものである。上記極端部の位置はこの点線が周方向と同じ方向（径方向と垂直方向）になっている位置である。すなわち極端部と極中心位置での配向方向は径方向あるいは周方向に対して互いに直角である。図３の点線は概略で示しているが、実際の磁石を構成する磁粉の方向は１００％の磁粉がこのような点線を向かせることは困難である。磁粉の大きさは数μｍ以下であり、その粒径が分布しており、形状も完全に同一でなく、配向磁界を印加しながらプレスすることもあり、磁粉同士が接触した状態で磁界方向に完全に方位を揃えることは困難になるのである。図２、図３、図５では、硬質磁性材の容易磁化方向の配向方向２を点線で示しており、極端部に保磁力の小さな軟磁陛材３を配置させている。軟磁性材３の位置に配置、形成させた保磁カの小さな部分は硬質磁性材１と一体で成形している。その手法は焼結工程前に軟磁性材３の位置に軟磁性材３の成形体を配置させる方法、焼結工程において軟磁性材３の部分の焼結温度等の条件を変える手法、焼結後に軟磁性材３の部分の磁気特性を変える手法などがある。

【００５４】
焼結前に軟磁性材３の部分に軟磁性材を配置させるには成形を２段に分けて成形体を作成後、焼結したり、軟磁性材３の部分の配向磁界を小さくしてその付近の磁気特性を変化させること、あるいは、極異方性磁石を配向成形後に軟磁性材３の付近のみに高い磁界を印加して磁気特性を変える手法がある。

【００５５】
焼結工程において軟磁性材３の部分の焼結温度等の条件を変える手法には、軟磁性材３の部分のみ通常の焼結温度よりも高くするか、低くすることにより保磁力を小さくすることが可能である。焼結後に軟磁性材３の部分の磁気特性を変える手法では、焼結、加工後に軟磁性材３の部分を過熱急冷することにより保磁力を低下させることが可能である。磁石が極異方性の配向ではなくても図１のラジアル配向をもったリング磁石の場合においても図に示すように軟磁性材３の部分を周方向に周期的に配列させることにより磁気抵抗差をつくることができる。

【００５６】
軟磁性材３の部分となる材料はＮｄＦｅＢ系の場合には粉の粒径を１桁以上他の部分より大きくして保磁力を小さくしたもの、ＮｄＦｅＢ系の組成で非晶質あるいは金属ガラスに近い準安定構造にしたもの、ＮｄＦｅＢ系の粉に磁気特性の異なる強磁性材（α－Ｆｅ、Fe_3B、Fe_4N、Fe_2O_3等）を混合させたもの、Ｆｅ－Ｓｉ合金等の軟磁気特性を有する磁性材を適用できる。

【００５７】
図６は、ＮｄＦｅＢ系磁石で極異方性に近いリングに図３に示すように内周側の軟磁性材３にＦｅ－３％Ｓｉ粉を用いて一体で焼結した場合の表面磁束密度の波形を示す線図である。用いた粉は$Nd_2Fe_{14}B$の異方性磁粉であり、保磁力（ｉＨｃ）が１５～２５ｋＯｅ、Ｂｒが１．１～１．３Ｔの粉である。軟磁性を示すＦｅ－３％Ｓｉ粉の位置（図３の軟磁性材３の位置）を除いて予めＮｄＦｅＢ系磁粉のみで配向成形させ、その後上記軟磁性材の粉を図３の軟磁性材３の位置に加圧成形する。この場合の軟磁性材の径方向体積率は２０％であり、周方向の（図３の軟磁性材３の位置の）幅は約５度である。この角度は１極の角度（８極の場合４５度）の１／２以下が望ましい。配向に必要な磁界は５０００Ｏｅ以上である。その後上記成形体を真空炉に入れて加熱焼結する。焼結温度は８００～１２００℃である。焼結後に加工して、必要に応じて表面保護膜を形成する。図３は８極の場合を示しているが２極以上のいずれの極数の場合でも作製可能である。

【００５８】
図６において縦軸は相対値であり横軸は角度である。磁石外径は３０ｒｎｍ、内径は２０ｍｍであり、高さ２０ｍｍである。測定位置は外周側の高さ１０ｍｍであり、ホール素子を用いて径方向の表面磁束密度を測定した。表面磁束密度の波形は正弦波に近く、その波形歪は約４％である。また、表面磁束密度のピーク値は、同一形状で作製したラジアルリング磁石と同等以上であった。

【００５９】
（実施例７）
図７は、実施例６において径方向の軟磁性材の体積率を多くした場合について検討した軟磁性材の体積率と表面磁束密度の波形歪との関係を示す線図である。図７に示すように、軟磁性材の体積率が増加すると表面磁束密度の波形歪が増加する。また、図８に示すように、透磁率も軟磁性材の体積率の増加によって増加するが、特に２０％までが急激に増加している。

【００６０】
図７のように表面磁束密度の波形歪が増加するのは、軟磁性材の粉の存在によって硬質磁性材の粉であるＮｄＦｅＢの粉の配向が悪くなること、軟磁性材と硬質磁性材の粉との間の拡散などによる磁気特性劣化が原因として考えられる。リラクタンストルクを確保して波形歪を抑制するためには軟磁性材の径方向体積率を５～５０％にすることが望ましい。この範囲でリング磁石の極中心における透磁率は１．０～１．０５である。これは図５において軟磁性材の粉を径方向１００％としているが、軟磁性材３の部分を軟磁性と硬質磁性の混合体の方が波形歪低減には効果があることを示している。

【００６１】
（実施例８）
図９及び図１０は、実施例１～７で製作したリング磁石を用いた回転子の斜視図である。回転シャフト１２の軸方向中央にリング磁石１１を有機系の接着剤を用いて接着している。モータの構造により内周側に軟磁性材を設けるか、外周側に設けるか異なる。また、極異方性リング磁石の配向もアウターローターに使用する場合は内周側に磁束が強くなるようにする。図１０に示すように軟磁性材１３を軸方向で傾斜させてコギングトルクを低減することも可能である。回転シャフト１２は、リング磁石１１を接着する部分（胴部）では、モータに必要なトルクに合わせた径とし、両側の回転シャフト１２に対して最も大径となっている。中間部は、回転シャフト１２としての強度を確保できる径を有するようにできるだけ軽量になるように細い径にしている。

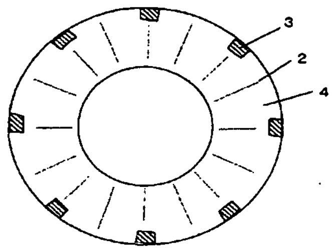
【００６２】
回転シャフト１２に軟鋼、Ｆｅ合金、Ａｌ合金、Ｃｕ合金等が用いられ、回転子の表面には、酸化、腐食を防止するために、Ｎｉめっき、化成処理等が施される。

【００６３】
図１１は、図９及び図１０の回転子を用いたモータの断面図である。本モータは、磁気抵抗の差を利用したリラクタンストルクが利用できるので、低回転数において高いトルクが

確保できるものである。特に、本モータは、低速で高いトルクが要求される内燃機関とモータとを備えたハイブリット自動車において有効である。
【００６４】
【発明の効果】
本発明によれば、リング磁石の表面磁束密度あるいは誘起電圧波形が正弦波に近く、又、リング磁石の極中心の配向を高め、かつ軟磁性材の粉を周方向に周期的に形成することで透磁率の差を周方向で発生させることが可能であり、表面磁束密度の波形歪が小さく、コギングトルクの小さい回転子を提供でき、更に、低回転数におけるリラクタンストルクを利用可能なモータに適用できる。特に、高効率のモータを製造でき、産業用、自動車用、半導体装置などの搬送、位置決めモータなどに適用できる。
【図面の簡単な説明】
【図１】本発明の軟磁性材を極端部外周側に周方向に周期的に設けたラジアルリング磁石の断面図。
【図２】本発明の軟磁性材を極端部外周側に周方向に周期的に設けた極異方性リング磁石の断面図。
【図３】本発明の軟磁性材を内周側の周方向に周期的に設けた極異方性リング磁石の断面図。
【図４】極異方性リング磁石の断面図。
【図５】本発明の軟磁性材を極端部の径方向に設けた極異方性リング磁石の断面図。
【図６】軟磁性部を周方向に周期的に設けて作成したリング磁石の外周側表面磁束密度を示す線図。
【図７】表面磁束密度の波形歪と軟磁性材の径方向体積率との関係を示す線図。
【図８】リング磁石の透磁率と軟磁性材の径方向体積率との関係を示す線図。
【図９】本発明のリング磁石を適用したモータ用回転子の斜視図。
【図１０】軟磁性材を軸方向に対して傾斜させた本発明のリング磁石を適用した回転子の斜視図。
【図１１】本発明の回転子を用いたモータの断面図。
【符号の説明】
１…硬質磁性材（極異方性リング磁石）、２…硬質磁性材の容易磁化方向の配向方向、３、１３…軟磁性材、４…硬質磁性材（ラジアルリング磁石）、１１…極異方性リング磁石、１２…回転シャフト、１４…固定子、１５…リング磁石。

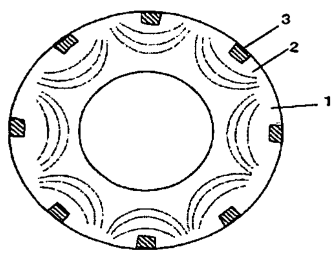
【図１】

図1



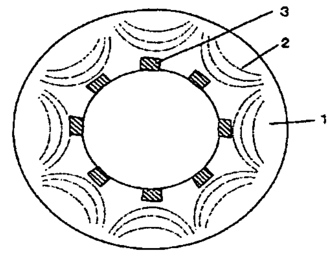
【図２】

図2



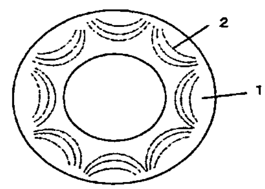
【図３】

図3



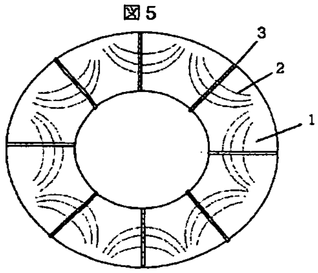
【図４】

図4



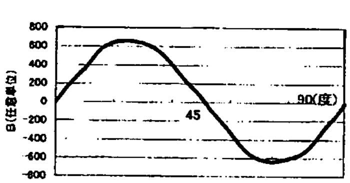
【図５】

図5



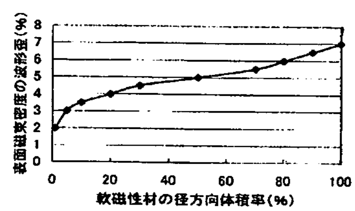
【図６】

図6



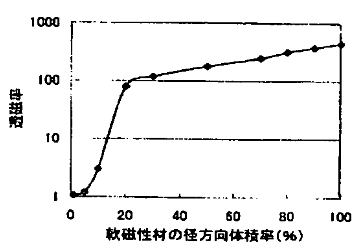
【図７】

図7



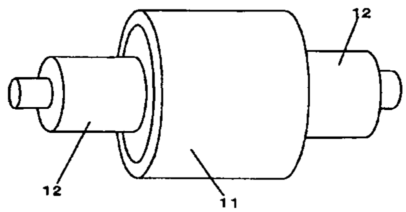
【図８】

図8



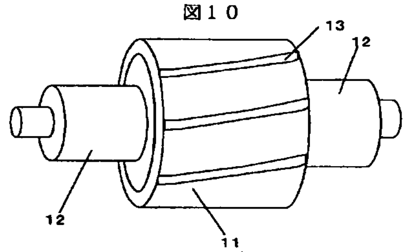
【図９】

図9



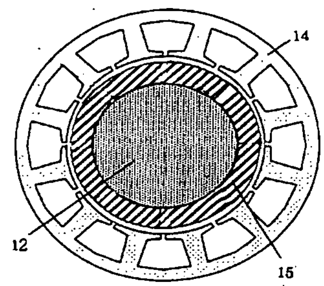
【図１０】

図10



【図１１】

図11



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(72)発明者 田島 文男
茨城県日立市大みか町七丁目１番１号 株式会社日立製作所日立研究所内
(72)発明者 栗山 義彦
埼玉県熊谷市三ケ尻５２００番地 日立金属株式会社先端エレクトロニクス研究所内

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